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Characterizing Succession Within a Forest Habitat Type—An Approach Designed for Resource Managers

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ABSTRACT

Describes a method for developing a general-purpose ecological model of community types and successional relationships within a forest habitat type (potential vegetation). This model is based upon data collected from a large number of seral stands, and it is intended for use in land management and planning. The successional model has a framework of structural stages subdivided into community types based on overstory and undergrowth composition. The usual pathways or directions of succession between community types are identified. To aid prediction of vegetational development after different treatments, the model shows apparent relationships among posttreatment vegetation and the original vegetation, site characteristics, and kind of treatment. This method was used in developing successional classifications (models) of four major forest habitat types in western Montana (Arno and others 1985).

KEYWORDS: vegetation classification, ecological modeling, vegetal response, effects of disturbance

Pfister (1980) concluded that no single modeling approach will meet all management and research needs for understanding succession. In fact, a diverse array of methods have been used to model various aspects of forest succession (Kessell 1981; West and others 1981; Means 1982). In the Northern Rocky Mountains several types of successional models have been developed to meet different needs (Stage 1973; Kessell and Potter 1980; Wykoff and others 1982; Fischer and Clayton 1983; Steele 1984; Steinhorst and others 1985). Nevertheless, little attention has focused on presenting successional community types in a manner that would allow resource managers to predict response to alternative treatments. The method outlined in this paper addresses this latter need by modeling succession within a "habitat type" or "vegetation association," representing the end-point of succession (Daubenmire 1968; Pfister 1984).

Our approach produces a general-purpose ecological classification of the seral community types on a given habitat type and also serves as a guide to help users confirm the habitat type of seral stands. A model shows the usual pathways of succession and allows land managers to compare results of different treatments and site conditions. An interactive computer program developed as a companion to this model supplies quantitative predictions of vegetal response to treatments (Keane 1984).

SCOPE OF THE CLASSIFICATION

To apply this classification technique, we recommend selecting a geographic area or region having similar patterns of vegetational types and zonation (Arno 1979).

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For example, the western Montana classifications (Arno and others 1985) apply on about 5 million acres of land and fit less well outside of this core area. Classifying successional communities on a group of related habitat types that lie adjacent to each other allows for more efficient sampling and better insight for modeling vegetal relationships.

Successional communities arising after common disturbances or treatments are candidates for classification. For instance, our Montana classification dealt with stand-replacing wildfire, clearcutting followed by broadcast burning, clearcutting with dozer piling and burning, and clearcutting with no followup treatment. If consistent applications of any partial cutting treatment have been made over considerable acreages within a habitat type, the resulting communities can be sampled and classified. Postfire communities ranging in age from 1 year to more than 200 years may be available for sampling, whereas stands arising after clearcutting treatments commonly range up to about 30 years of age.

We recommend sampling a large representation of the posttreatment communities available and watching for the opportunity to sample adjacent untreated stands or stands with different treatments on similar topography and soils. This will yield large numbers of samples for the money invested. The determination of when to stop sampling additional stands depends on the level of resolution needed within the classification, which is a function of intensity of land management. Normally, continued sampling can be questioned when new stand data begin to show a very high proportion of redundancy.

SAMPLING PROCEDURE

The first step in selecting sample stands is to obtain information from local foresters for locating stands that represent a range of ages for each kind of treatment in each habitat type. A computer-sort of available stand inventory data can identify kinds and ages of treatment units by habitat type or by aspect-elevation criteria. Bear in mind, however, that inventory data may have errors in habitat type determination. Soil surveys can be consulted to see if the same habitat type occurs on dissimilar soils. If so, soils may be included in the stratified sampling scheme. Take reconnaissance trips to identify potential sample stands, recording the extent and homogeneity of the plant community, principal tree and undergrowth species, uniformity of treatment and site conditions, stand age, habitat type, and evidence of artificial regeneration.

After reconnaissance has been conducted in many areas, select stands for sampling with a goal of obtaining geographic dispersion of samples as well as a range of ages for all treatments and a representation of all apparently different plant communities (Pfister and Arno 1980). Stands on the same site representing different ages or treatments should be given priority for sampling because they provide comparisons of differential response to treatments and they allow indexing the treated stands to an association. After tentative selections have been made, a two-person team can sample three to six stands in a 10-hour field day.

We suggest sampling a single 375-m^2 (nearly 1/10-acre) circular macroplot in each stand (Pfister and others 1977; Steele and others 1983). After inspecting the stand, the macroplot should be located subjectively in an area that seems to have a representative overstory and undergrowth composition and treatment uniformity. This form of macroplot location is termed "subjective but without preconceived bias" (Mueller-Dombois and Ellenberg 1974; Pfister and Arno 1980). The principal advantage of the single macroplot is that it enables the investigator to obtain quantitative data of adequate precision on twofold to fourfold as many stands per day as can be sampled in methods that require many microplots. Methods that use microplots or belt transects may be required if quantification of intricate disturbance patterns is necessary, such as in studies of pocket gopher damage. Canopy coverage for each tree and undergrowth species can be estimated in broad percentage classes for the macroplot—for example, a 0 to 1 percent class; 1 to 5 percent; 5 to 15 percent; and in 10 or 20 percent classes thereafter. To enhance consistency of macroplot coverage estimates, samplers should initially compare them with averages derived from 50 small plots systematically placed within the macroplot. The size of small plots should be related to the vegetational life-form being sampled. The macroplot estimates can then be adjusted to coincide with values derived from small plot estimates.

In stands having a treatment mosaic, such as those resulting from bulldozer pile-and-burn operations, it may be desirable to locate smaller sample plots in each element of the mosaic and also to estimate the percentage of the area represented by each element. It may also be possible to meet study goals in areas having a treatment mosaic by sampling one macroplot per stand, with the plot situated in an average representation of the mosaic elements.

Trees in the macroplot are tallied by species and diameter size classes (for example, 2-inch classes). Stand history is determined from tree growth rings in order to augment and verify available management records. Trees regenerating after the treatment are increment-bored or cross-sectioned near ground line to obtain total age. Also, residual overstory or small understory trees that survived the treatment, including those on the unit boundary, often show growth release and mechanical scars that can be used to date the treatment (Arno and Sneck 1977).

Relative severity of treatment can be estimated in broad classes (for example, light, moderate, heavy, and extreme) from the percentage of exposed mineral soil and from average depth of humus and duff compared with untreated stands. It may be necessary to use transects for comparing fuel or duff reduction (Brown and others 1982). In broadcast-burned stands, changes in soil color and the completeness of combustion in various size classes of down fuel provide similar insight (Ryan and Noste 1985). Treatment severity is more difficult to rate in older seral stands because of vegetal recovery; but evidence of woody fuel consumption, soil organic layers, and tree survival may still make a general evaluation possible. As a minimum, texture of the mineral soil and the type of soil parent material should be recorded in

each stand. Characterization of soils to the family level is desirable for evaluating potential vegetation on treated sites lacking adjacent untreated communities.

Quantitative evaluation of both natural and planted tree regeneration should be made on treated sites, and management records of tree planting or seeding should be checked. One simple approach is to estimate established regeneration in three classes for each young stand: "adequate regeneration" (for example, more than 250 well-distributed trees per acre), "inadequate regeneration" (for example, 100 to 250 trees per acre or poor distribution), and "nonstocked" (for example, less than 100 trees per acre). In order to calculate growth rates for each species related to seral community types, heights and total ages (from increment borings near ground level) can be obtained from vigorous dominant or free-growing trees of each species (Pfister and others 1977).

DATA ANALYSIS

By the end of one or two field seasons, enough stands should have been sampled to warrant the initial attempt (first approximation) at successional classification (fig. 1). Plot data should be coded for computer analysis, in a format compatible with existing software packages.

A first step in constructing the classification is to evaluate the variation within each habitat type (or association), using data from all mature stands. This will determine if the defined habitat types and phases are sufficiently detailed to serve as the basis for classifying successional patterns in a limited geographic area. Synthesis or association tables, index-of-similarity ordinations (Bray-Curtis polar ordinations), cluster analyses, and other comparable techniques are used to compare all the untreated stands in each habitat type (Mueller-Dombois and Ellenberg 1974; Gauch 1977; Volland and Connelly 1978; Pfister and Arno 1980). Data from mature stands are arranged along inferred environmental gradients (in ordinations), and consistent differences in the presence and canopy coverage of individual species and groups of species (including herbs, shrubs, and trees) are examined (Peet 1980; del Moral 1983). The vegetational patterns are inspected to see if they are linked to differences in site data, such as elevation, aspect, topographic position, and soils. Data from younger communities are also inspected in a similar manner to see if community composition seems to reflect consistent site-related differences within a defined habitat type or association.

In the Montana successional study (Arno and others 1985), we inspected data from mature stands in four previously defined habitat types and decided to split these into a total of seven local habitat type phases representing different potential vegetation types. The habitat type phases, like all other components of the successional classification, should be presented as a hypothesis and should be tested and critiqued by at least three vegetation researchers. The classification will benefit if conducted as an interactive team effort, since that will expose it to continued reevaluation and differing points of view.

Each habitat type phase identified represents the end point of succession and thus serves as the basis for a separate successional classification or model. The model of seral community types and successional pathways within a habitat type phase is constructed using data from all stands representing the phase. In some cases it is not possible to determine the habitat type phase of a seral stand despite inspection of stumps and remnants of pretreatment communities on the site or untreated stands on similar topography and soils. It is preferable to use data from stands where the potential vegetation type can be reliably projected for construction of a successional classification. Data from stands where the potential vegetation is not predictable can later be compared to see if they fit within the successional classification.

The first step in setting up the classification framework is to define structural stages by examining the following data (or other comparable kinds of information) for each stand: years since treatment, total canopy coverage of trees, average diameter of dominant trees, and basal area of trees. Based on these data, sort the individual stands into logical structural groups. For example, the structural stages we designated in western Montana were: shrub-herb, sapling, pole, mature forest, and old-growth forest (compare with Thomas 1979; Foote 1983). In other successional studies an herbaceous stage, a seedling-dominated stage, or even a climax forest stage might be prominent and thus worthy of recognition. Criteria for each of these "structural stages" may differ among the habitat type phases because of differences in the rates of vegetal development and site productivity.

Species composition provides the criterion used in designating community types. Starting with early seral stages, identify compositionally similar groupings among the sample stands, using synthesis tables, polar ordination, cluster analyses, and so forth. Here one must employ a certain amount of judgment based upon field experience with the stands. Community types are based upon and named for major species in the overstory and undergrowth, or for individual species or groups of ecologically similar species that show consistent successional relationships.

In the successional classification (fig. 2), structural stages are arranged horizontally and community types are listed vertically. Shade-tolerant undergrowth species (for example, VAGL, *Vaccinium globulare* in fig. 2), are characteristic of pole stage and older communities; however, under certain conditions they are also major components of the younger stages. Other species are "seral dominants" (for example, CEVE, *Ceanothus velutinus*) and become common only after major disturbances. After designating the preliminary community types, construct a simple step-wise key to them for field use (fig. 3). All sample stands used in the classification should be run through the key as an initial test.

Next, the usual pathways of succession (arrows on fig. 2) should be illustrated. Probable pathways can be determined through analysis of data from sample stands of different ages, particularly those occupying the same site. Canopy coverage trends of successional species also provide evidence for pathways. For instance, coverages of evergreen ceanothus (CEVE) and young conifers are inversely related (fig. 2). In contrast, huckleberry

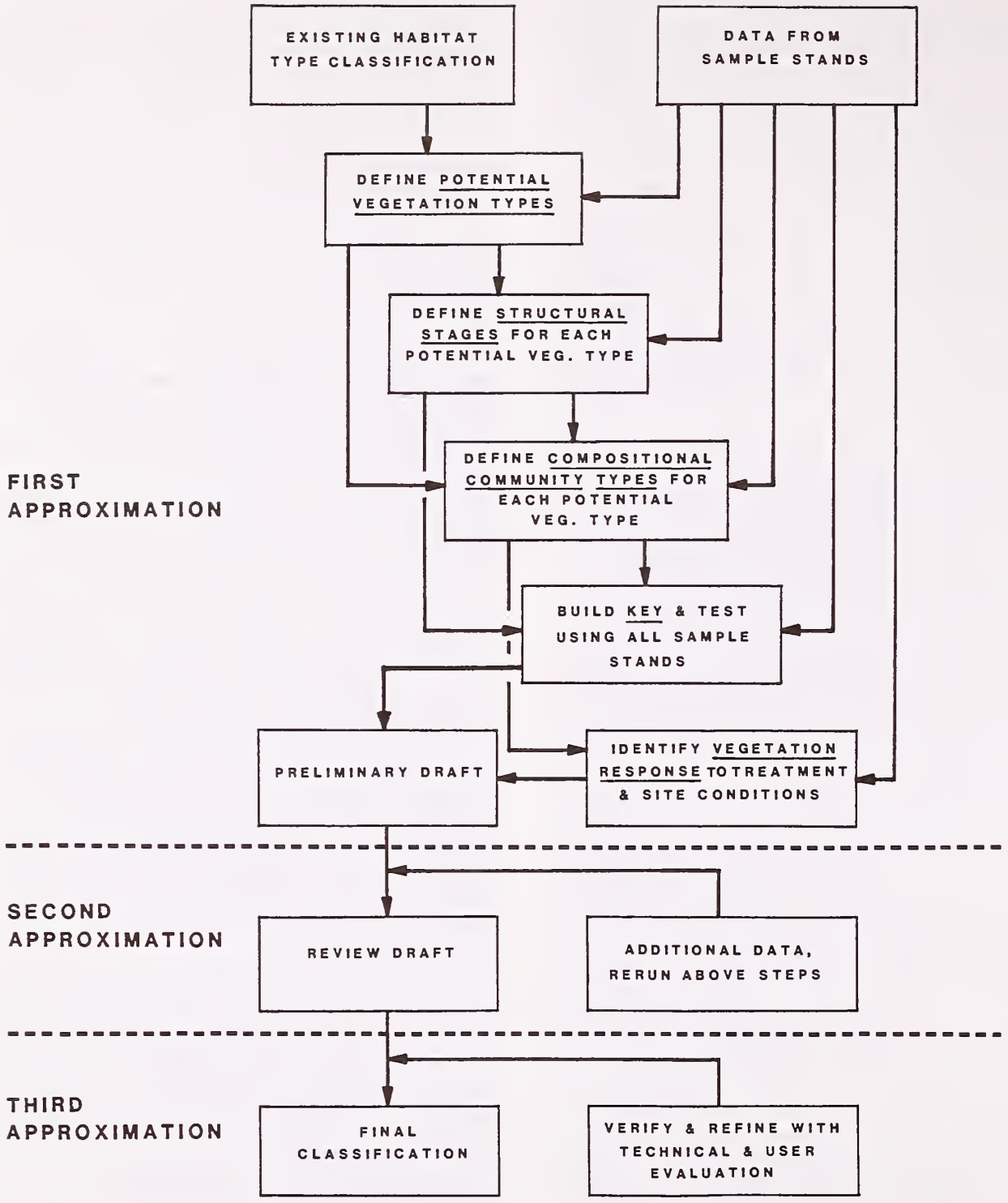
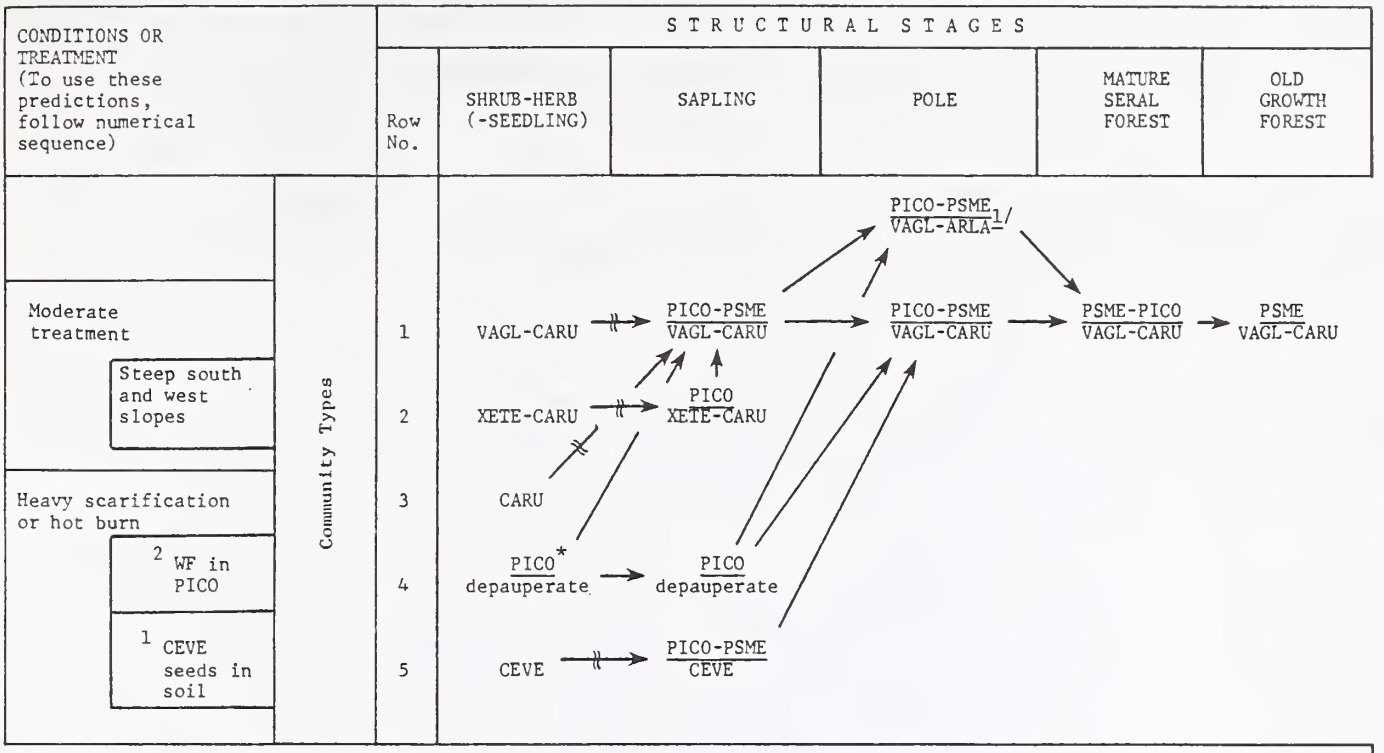

EXISTING HABITAT TYPE CLASSIFICATION
DATA FROM SAMPLE STANDS
DEFINE POTENTIAL VEGETATION TYPES
DEFINE STRUCTURAL STAGES FOR EACH POTENTIAL VEG. TYPE
DEFINE COMPOSITIONAL COMMUNITY TYPES FOR EACH POTENTIAL VEG. TYPE
FIRST APPROXIMATION
BUILD KEY & TEST USING ALL SAMPLE STANDS
PRELIMINARY DRAFT
IDENTIFY VEGETATION RESPONSE TO TREATMENT & SITE CONDITIONS
SECOND APPROXIMATION
REVIEW DRAFT
ADDITIONAL DATA, RERUN ABOVE STEPS
THIRD APPROXIMATION
FINAL CLASSIFICATION
VERIFY & REFINE WITH TECHNICAL & USER EVALUATION

Figure 1—Flow chart showing the development of a successional classification.



1/ ARLA >5% C.C.

Stand Characteristics by Structural Stage
(Range represents about 90% of the data; extreme values are shown in parentheses)

Range of values from sample stands	Tree canopy coverage percent	0 - 15(30)	15 - 90	60 - 90	55 2/ - 72	45 - 70
	Average d.b.h. of dominant trees (inches)	0 - 2	2 - 5	6 - 10	11 - 16	14 - 24
	Basal area (ft^2/acre)	0 - 9	3 - 90(143)	45 - 130(321)	120 - 240	140 - 330
	Stand age (yr)	4 - 23	12 - 32(54)	(25)39 - 90	100 - 230	190 - 300+
Number of sample stands		51	33	13	9	15

TREES:
PICO = Pinus contorta
PSME = Pseudotsuga menziesii
// = Establishment of tree regeneration delayed ≥ 20 years

UNDERGROWTH:
CEVE = Ceanothus velutinus
CARU = Calamagrostis rubescens
VAGL = Vaccinium globulare
XETE = Xerophyllum tenax
ARLA = Arnica latifolia

2/ In two stands one-half or less of the coverage was from overstory trees.

Figure 2—Successional community types on the PSME/VAGL habitat type, XETE phase in western Montana. The box at the left shows the apparent relationship of conditions and treatment to posttreatment community type, based on sample data (Arno and others 1985).

(VAGL) tends to expand beneath the newly developing tree layer in a sapling stand. The process of identifying probable pathways based on stand data and ecological relationships provides additional insight for evaluating and refining the initial community type categories.

The posttreatment communities are presumably a result of (1) the pretreatment vegetation, (2) seed dispersal from off site and from seed on the site (stored in the soil), (3) site conditions, and (4) the kind of treatment applied. The kind and intensity of treatments can be compared for each early seral community type. Similarly, pretreatment vegetation from paired stands can be compared among the early seral community types. Site characteristics (slope steepness, cool versus warm aspect, soil texture, parent material, and geographic location) can also be inspected for possible relationships to the posttreatment community types.

1. Select the most appropriate **community type row number** for the stand in question through use of the undergrowth key below (first priority). Then compare the tree species composition (second priority) with the community type names for that row in figure 2.

Stop at the first requirement that fits:	COMMUNITY TYPE ROW NUMBER (in fig. 2)
a. *Ceanothus velutinus* >5% canopy coverage (C.C.)	5
b. *Vaccinium globulare* >5% C.C.	1
c. *Xerophyllum tenax* >5% C.C.	2
d. *Calamagrostis rubescens* or *Carex geyeri* or their combined coverages >25%	3
e. Dense *Pinus contorta* seedling or saplings.	4

2. Select the most appropriate **structural stage** for the stand by comparing it with the stand characteristic values listed in figure 2 for tree canopy coverage, average d.b.h. of dominant trees, stand basal area, and stand age.

3. Inspect appendix A-3 (Arno and others 1985) which shows constancy and average canopy coverages of different species in each community type. Is the stand in question compositionally similar to sample stands shown in the indicated community type? If so, it apparently "fits" that community type. If it is dissimilar in terms of major component species, compare it with the other community types listed. It may fit one of those types, or it may not fit this classification as was the case with three of the 124 stands (2.4 percent) we sampled.

Figure 3—Key to successional community types within the PSME/VAGL habitat type, XETE phase (from Arno and others 1985).

Relationships of seral community type to treatment may be very unclear at first, but may improve as additional stand data are obtained during the course of the classification effort. These linkages are first presented as very tentative hypotheses, which are then repeatedly subjected to reevaluation as new data are obtained. Apparent relationships of the posttreatment community types to the original vegetation, site conditions, and treatment are shown in the boxes at the left in figure 2.

Substantial amounts of data obtained from paired or multiple stands on the same sites provide a basis for evaluating responses of undergrowth species to each kind of treatment. To do this, construct tables comparing canopy coverages by species in paired untreated and treated stands (table 1). Establish quantitative criteria to describe apparent trends for each species by treatment. For instance, our Montana data (Arno and others 1985) were sufficient to describe the trends of principal species as "increase," "decrease," "little change," or "variable and inconsistent changes." Species response interpretations can be improved and expanded by comparing findings from other studies dealing with similar vegetation (for example, McLean 1969; Flinn and Wein 1977; Stickney 1986; Volland and Dell 1981).

General interpretations can also be made regarding the success of artificial and natural tree regeneration by habitat type (Fiedler 1982; Arno and others 1985). Tree regeneration is compared in relation to kind and intensity of treatment and to site characteristics and competing vegetation. Artificial and natural regeneration should be rated separately; they are usually not difficult to differentiate by consulting planting records and observing spacing patterns and tree ages. More definitive assessments of regeneration require intensive surveys.

TESTING AND REFINING

It is useful to carry out sampling during a period of 2 or more years and to repeat the analysis with the expanded data bank in order to arrive at a revised successional classification or "second approximation" (Pfister and Arno 1980). This can be distributed to potential users as a review draft. We recommend holding a workshop to introduce potential users to the successional classification and to have them try it out in the field with guidance. Considerable effort should be invested in making the classification straightforward and easy to apply for users with a modest ecological background.

We recommend setting up a verification study of the review draft classification to be conducted by an investigator who was not involved in its development. The verification consists of two parts: (1) a field test of the draft classification carried out by the investigator on large numbers of seral communities, and (2) a field test of some of these same communities carried out by potential users under the guidance of the investigator.

In the verification effort, the classification is applied to seral communities representing all of the sampled treatments in the habitat type under investigation. At

Table 1—Percentage cover for selected species within five paired *Pseudotsuga menziesii/Vaccinium globulare, Xerophyllum tenax* stands before and after a clearcut-hot broadcast burn treatment; time since treatment ranged from 14 to 23 years

Species	Pre-treatment	Post-treatment	Interpretation
VAGL	72	<1	
	54	<1	
	54	3	Decrease
	15	3	
	37	28	
CEVE	<1	<1	
	0	4	
	0	15	Increase
	<1	37	
	0	85	
XETE	72	<1	
	46	<1	
	72	15	Decrease
	37	22	
	46	46	
CARU	8	8	
	15	15	
	37	15	Little change
	3	22	
	37	37	

each stand the evaluation procedure consists of the following steps, with questions, problems, and suggestions recorded in relation to each step:

1. Select a test stand, identify its habitat type or phase, and determine if the successional classification should apply to it.
2. Choose a representative area within the stand for sampling.
3. Complete the field form recording coverages of indicator species (for example, p. 74 in Arno and others 1985).
4. Using the successional classification key (fig. 3), identify the community type.
5. To confirm the choice of a community type, compare compositional data from this stand with data for the community type in the review draft.

The evaluations show how well the classification and key fit and point out numerous opportunities for improving clarity. The verification effort also provides additional data for refining the classifications, because canopy coverage information is collected at each test stand using the field form.

Users should be introduced to successional classifications via guidelines that help them determine which habitat type phase and, therefore, which classification applies to a given seral stand (for example, p. 9 in Arno and others 1985). The user then consults the key to the seral community types, which is applied in conjunction with the classification diagram and with tables summarizing species composition by community type. A narrative explains the successional diagram or model.

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